



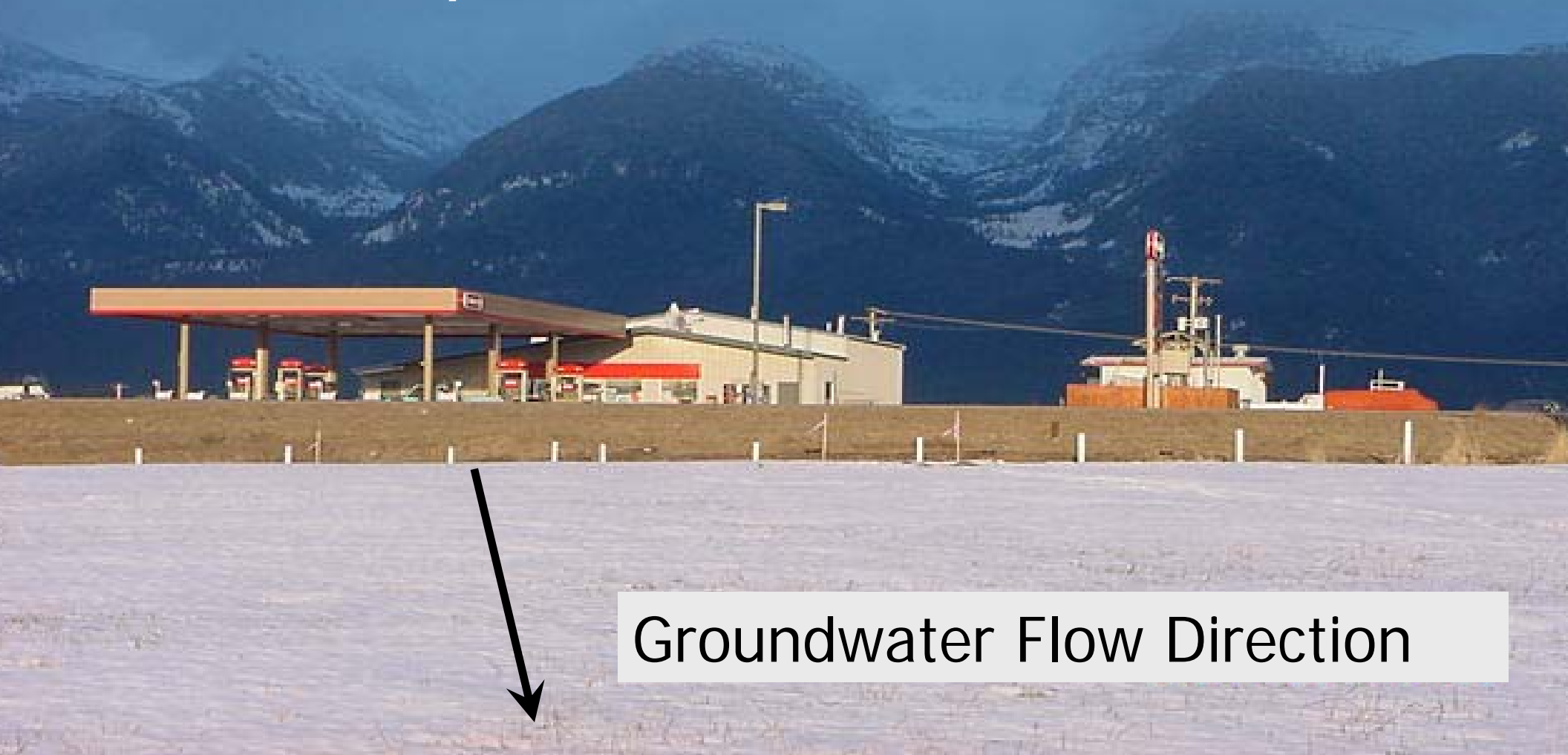
# **Remediation of a Gasoline Plume in a Fine-grained Aquifer in Northwestern Montana using Electrical Resistance Heating (ERH) Technology**

**Patrick J. Skibicki  
Montana Department of  
Environmental Quality**

**The 19th Annual AEHS Meeting and West Coast Conference  
on Soils, Sediments, and Water  
March 9 – 12, 2009, San Diego, California**



# Former George's Conoco Ronan, Montana







## Site History

- 1994 - Gasoline release discovered
  - Source was perforated 16,000-gallon UST
  - Original estimate was 6,000 gallons
  - High concentrations of MTBE; up to 15,000 µg/L
- 1995 – Insolvent RP
  - LUST Trust Program becomes involved
- 1995 – 2002
  - Approximately 3,500 gallons of gasoline removed through free product skimming, soil vapor extraction (SVE), and air sparging



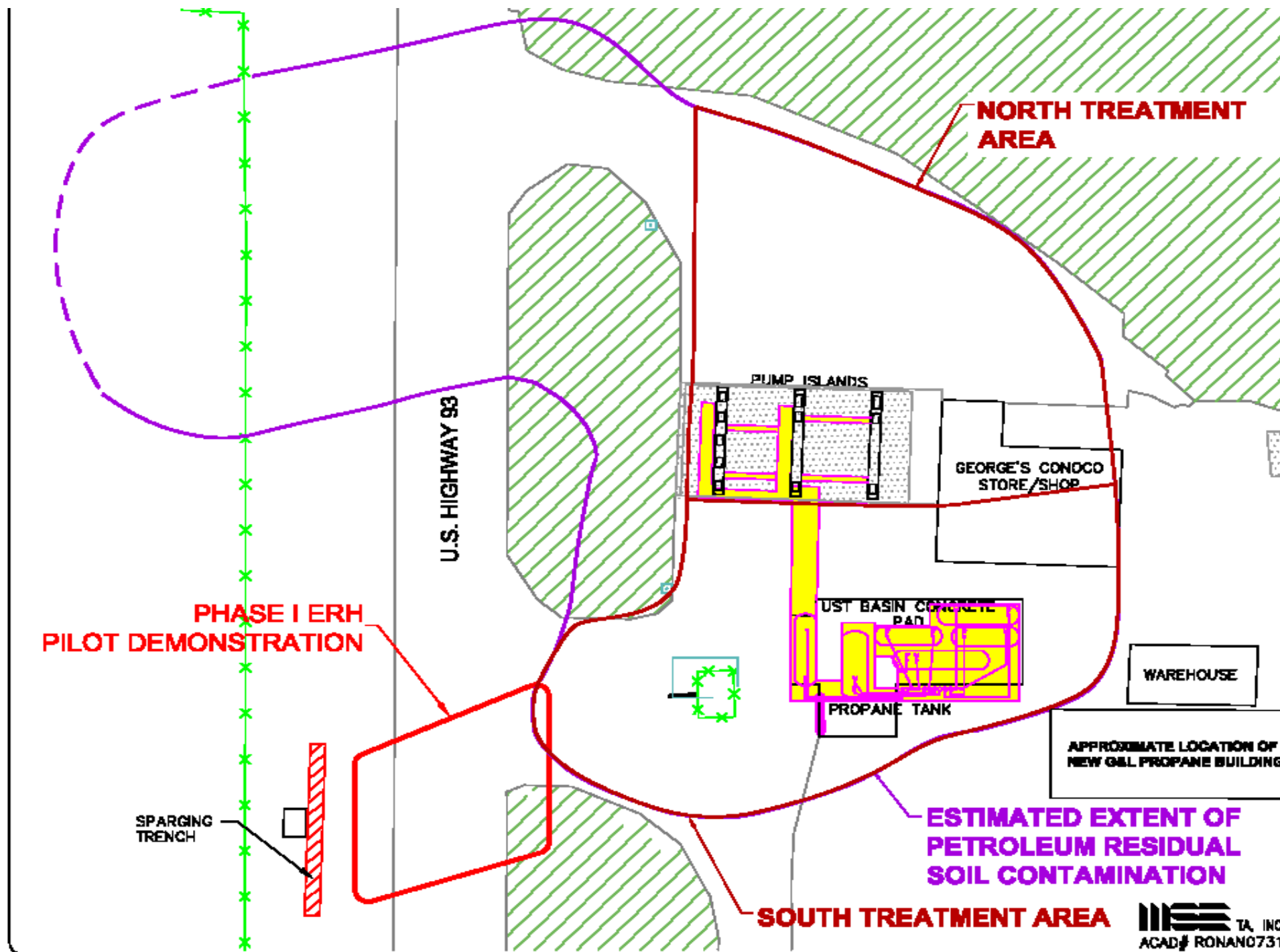
## Site History

- 2003 – Phase I ERH Pilot Demonstration Project
  - Treatment Volume – 2,771 cubic yards
  - 560 gallons of gasoline removed in 142 days
  - Almost complete removal of hydrocarbon mass from fine-grained soils within treatment zone
  - Demonstrated that ERH could be successfully implemented with air sparging on field scale
  - \$130 per cubic yard



## Site History

- 2006 & 2007
  - Additional (61) Geoprobe™ borings completed to assess residual source mass
  - Extent of on- and off-site soil and groundwater contamination greater than previously thought
  - Significant source mass beneath dispenser islands to depth of > 30 feet
  - MTBE not detected in North Treatment Area
  - Modified site conceptual model





## Site Characteristics

- Dominant Lithology within Treatment Zone
  - silt and fine-grained sand from approximately 5 feet to > 30 feet
- Depth to groundwater – 14 to 16 feet
- Groundwater flow – west - southwest
- Hydraulic Gradient – 0.004 ft/ft
- Avg Hydraulic Conductivity – 4.1 ft/day



## Site Characteristics

- ~ 1,500-foot long, 400-foot wide dissolved-phase MTBE/BTEX/TPH plume
- MTBE plume extends to Spring Creek, the primary receptor; benzene detected ~70 feet from Spring Creek
- Vertical component to dissolved-phase plume
  - MTBE detected at 865 ppb ~ 15 ft below water table; ~ 70 feet from Spring Creek



## Objectives

- Source area cleanup; North Treatment Area
- Reduce life span of dissolved-phase plume
- Protect Spring Creek
- Facilitate future redevelopment of George's Conoco Property
- Facilitate future development of privately owned alfalfa field; scheduled for Spring 2009





# Spring Creek



MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY

# Contractors

- MSE Technical Applications, Inc., Butte, MT
  - DEQ Contractor
- McMillan McGee Corporation, Calgary, AB
  - ERH Technology Vendor
  - Used their proprietary electro-thermal dynamic stripping process (ET-DSP™) technology





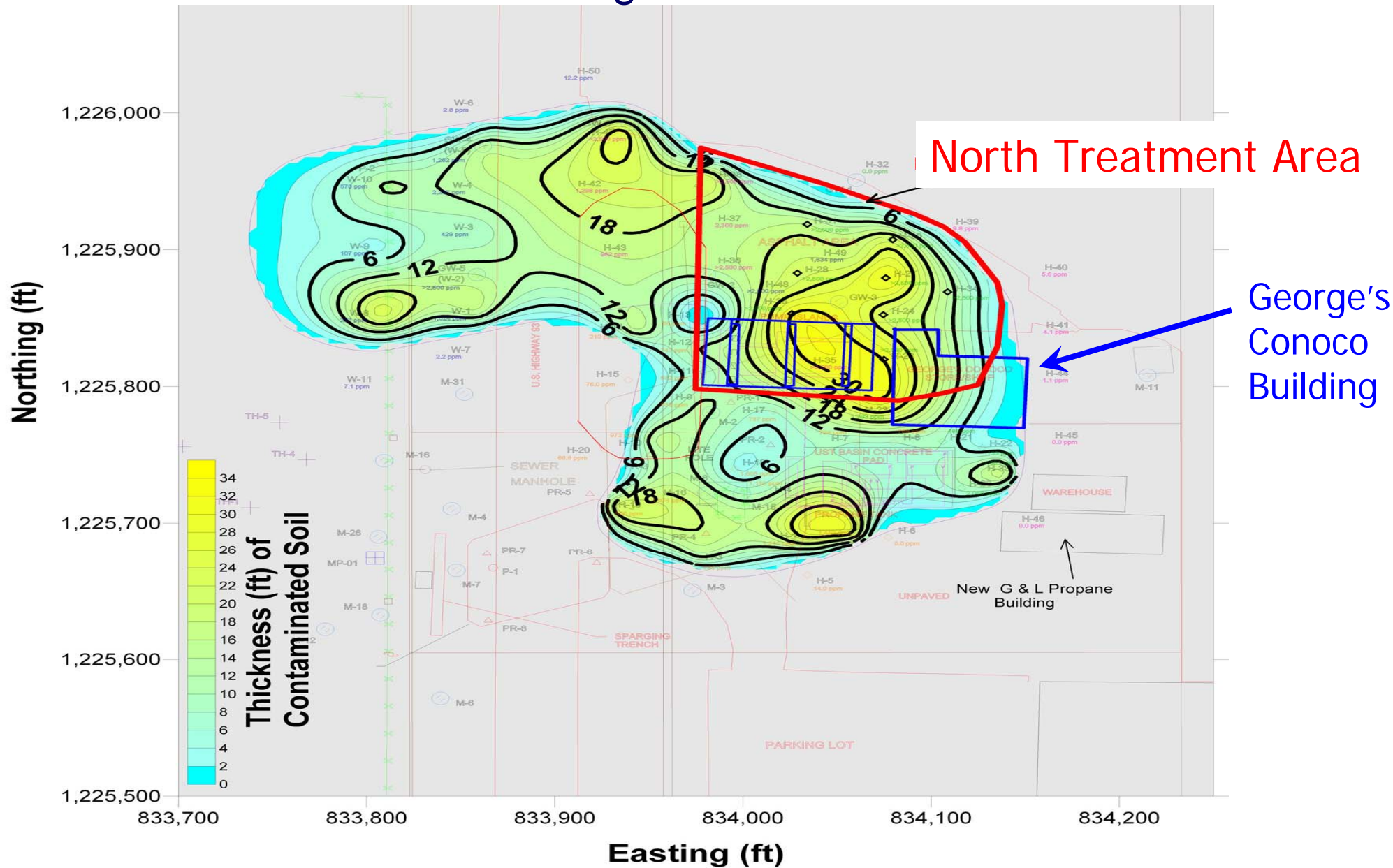
MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY

# Proposed Treatment Zone

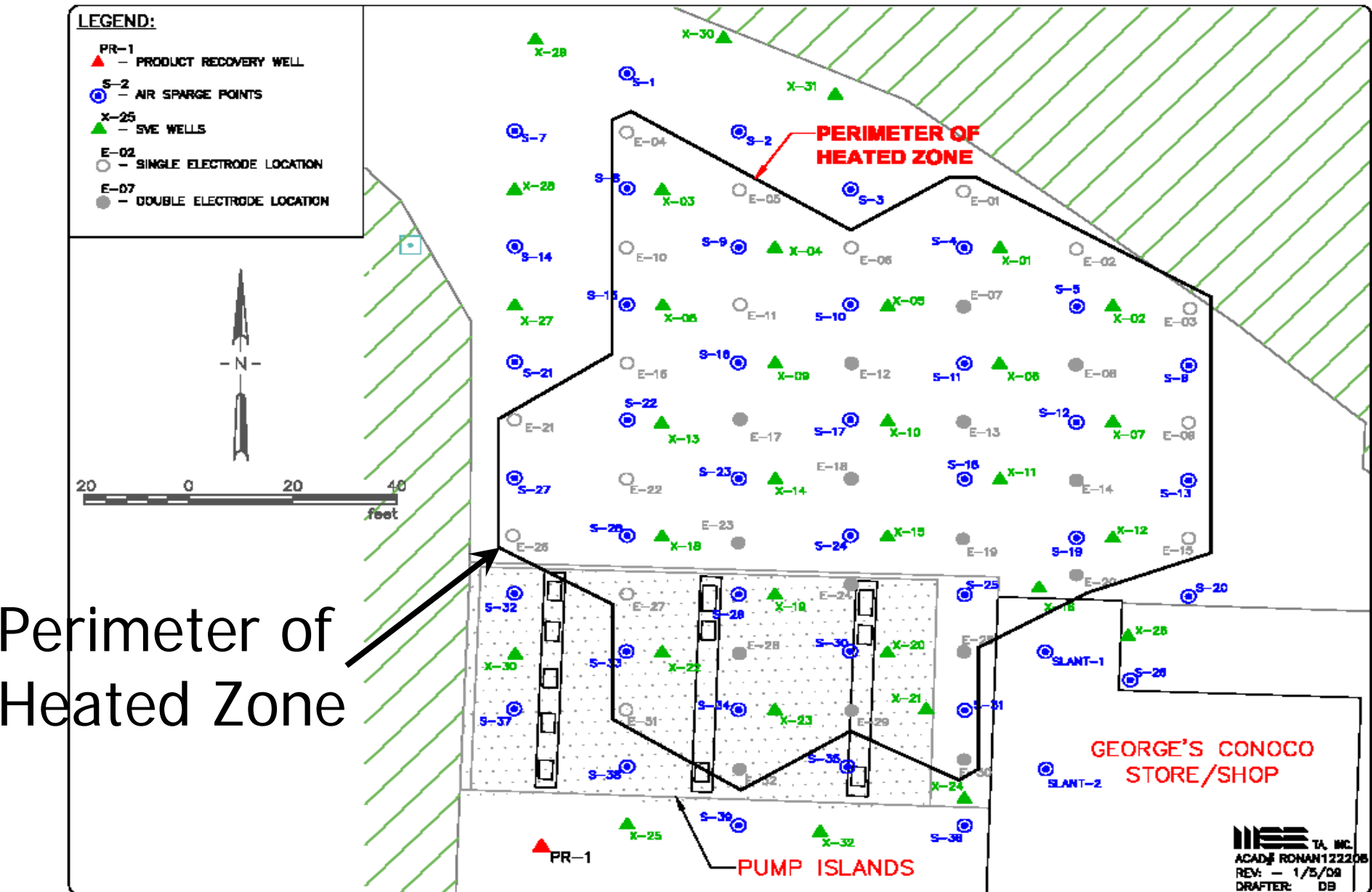
- North Treatment Area
  - Includes dispenser islands and area north of canopy
  - 12,220 cubic yards – estimated volume of soil within the North Treatment Area targeted for heating
  - Soils between 4 and 38 feet targeted for heating



**N**



# Locations of Electrodes, SVE wells, and Air Sparge Wells



## Project Design

- 48 total electrodes at 32 locations
  - 16 individual (single)
    - Set at 15 – 25 feet
  - 16 stacked (double)
    - Set at 7 – 17 feet & 25 – 35 feet
- Horizontal spacing – approximately 25 feet
- Electrode size – 8-inch diameter by 10 feet in length



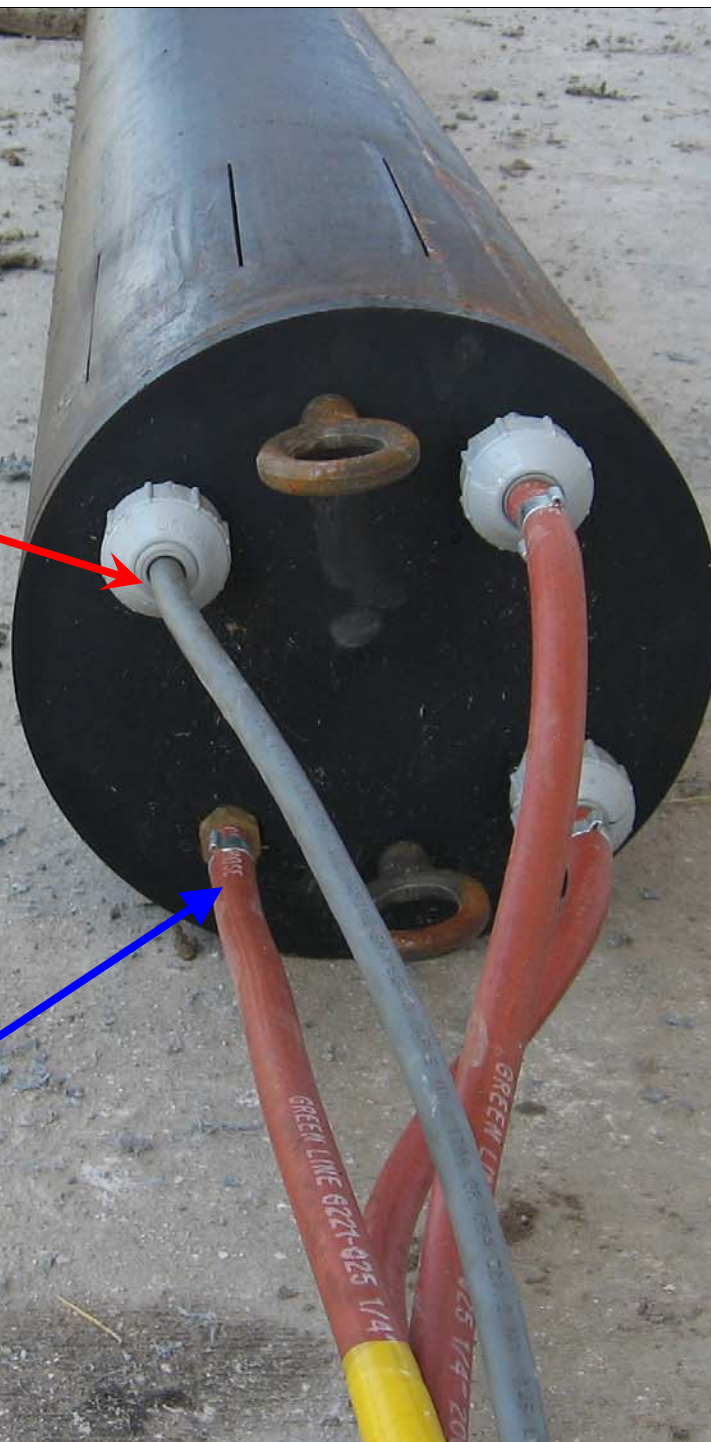
# Electrodes





Electrical  
Feed

Water Lines





# Project Design

- 41 total air sparge wells (3/4-inch diameter CPVC “temperature resistant”)
  - 39 vertical (screened intervals varied)
    - SI = 28.5 - 30 ft; 33.5 – 35 ft; or 38.5 – 40 ft
  - 2 slanted (beneath on-site building)
    - SI = ~34 – 35.5 ft
  - Spacing = ~ 25 feet
  - Sparge Points
    - 18-inch sparge point made of porous PE
    - Installed below heated zone (not temperature resistant)





Installation of Pre-Packed Air Sparge Well

# Project Design

- 32 SVE wells (2-inch diameter CPVC)
  - Screened Interval 10 – 15 feet
  - Spacing = ~ 25 feet
- 10 temperature monitoring strings; DigiTAMs™
  - Placed inside 1-inch diameter steel conduit
  - 10 data collection points per DigiTAM™
  - Spacing - Equidistant between electrodes; installed at “cool spots”

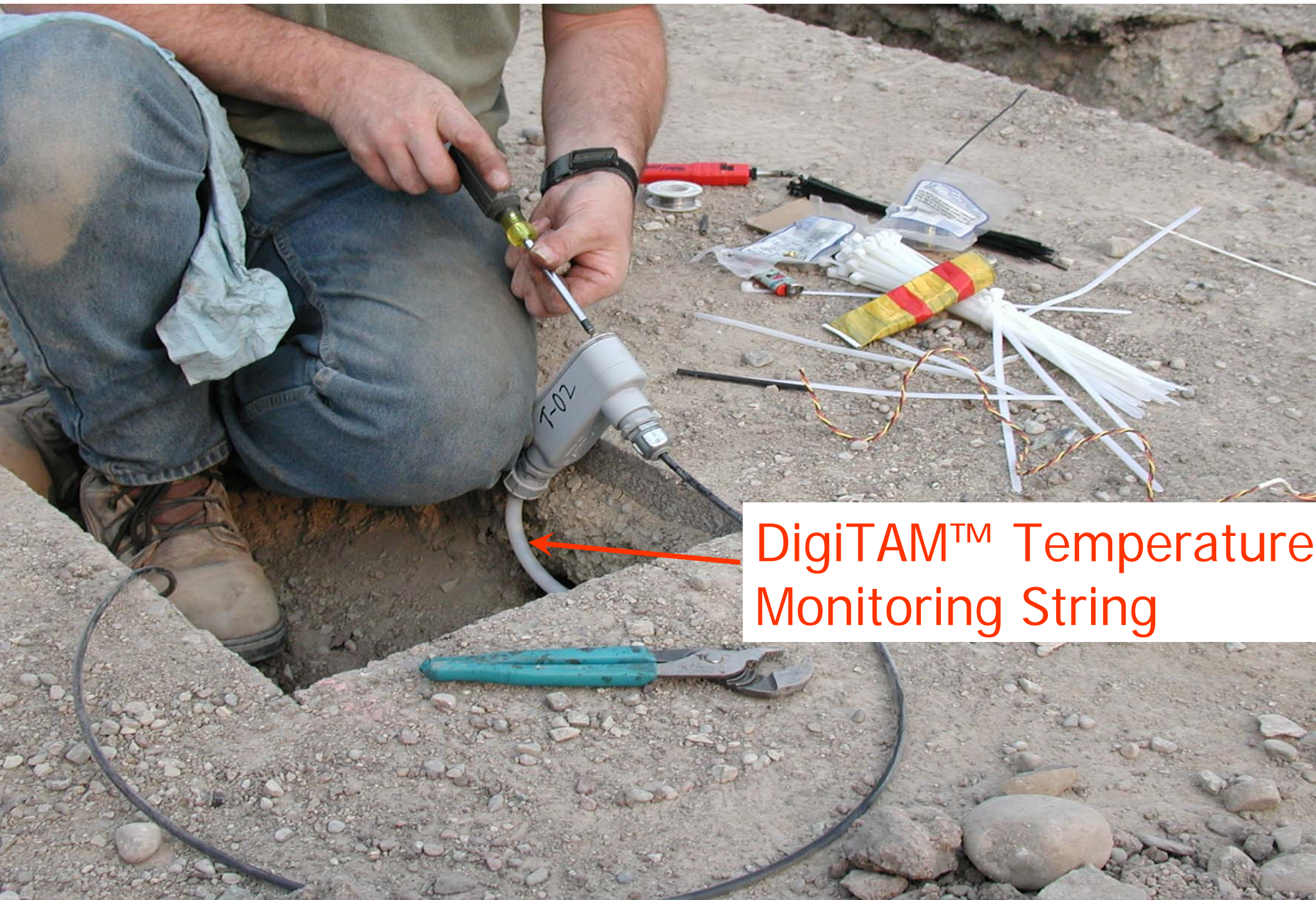




# SVE Well Installation







DigiTAM™ Temperature Monitoring String



# Target Temperature

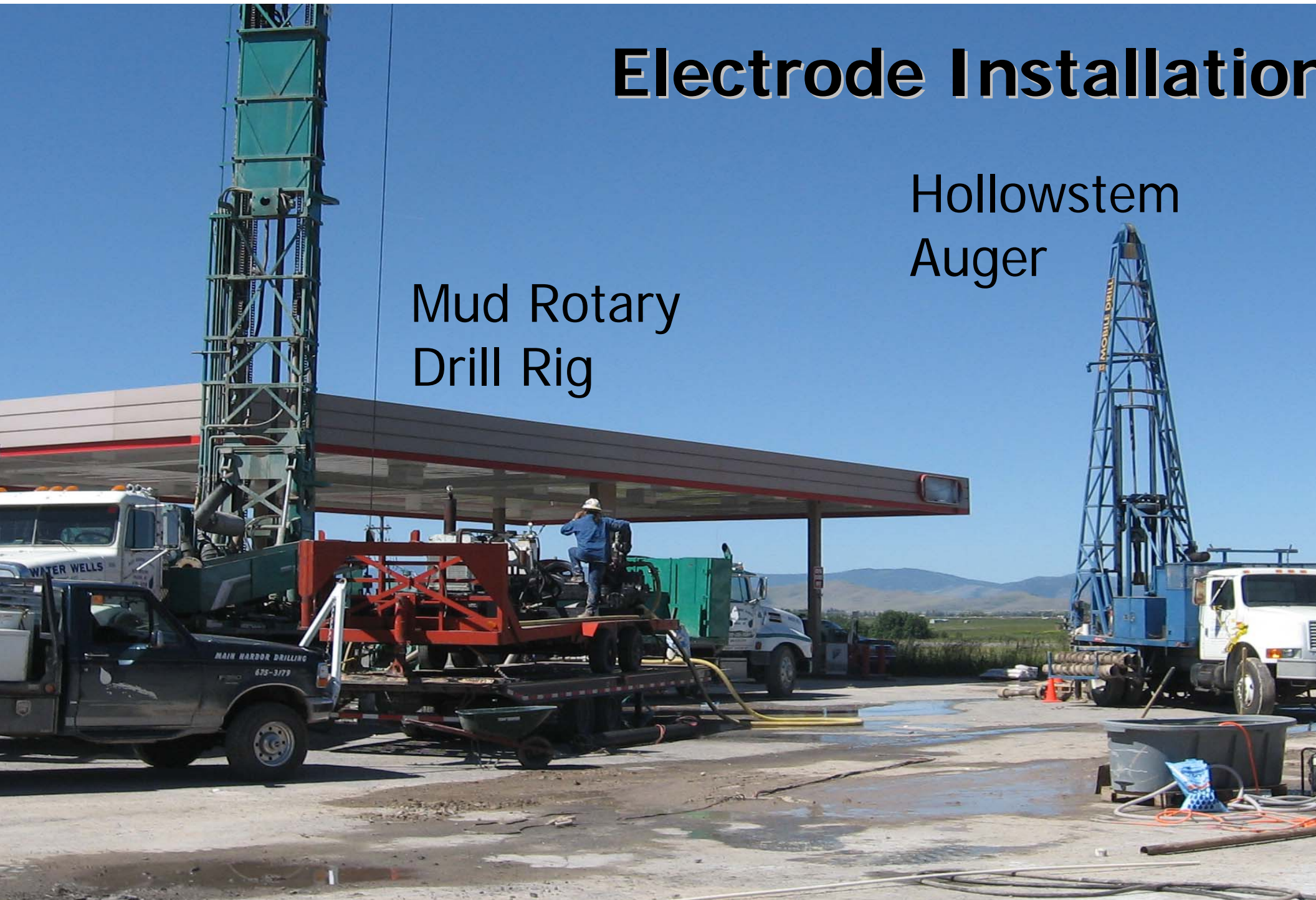
- 90 to 100 Degrees Celsius (C)
  - Boiling Point of Benzene = 80.1 Degrees C
  - Boiling Point of MTBE = 55.2 Degrees C



# Electrode Installation

Hollowstem  
Auger

Mud Rotary  
Drill Rig







Geoprobe Retrofitted for Mud Rotary Drilling



# Installation of Single Electrode





# Installation of Stacked (Double) Electrode

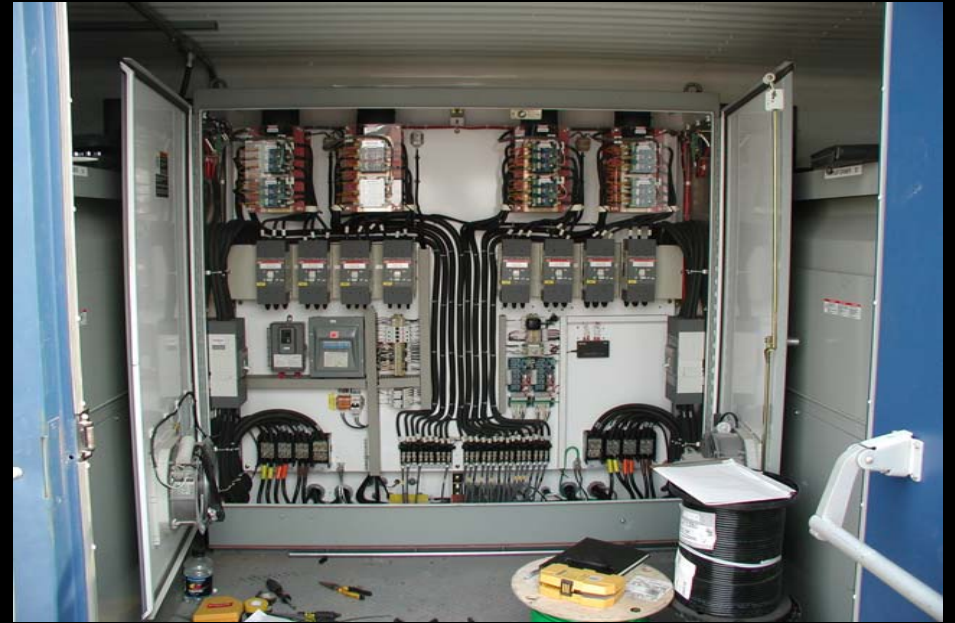






Air Sparge &  
SVE Equipment





## Power Delivery & Water Circulation Units



# Trenching and Installation of SVE, Air Sparge, DigiTAM™ and Electrode Lines





# Timelines

- June 5, 2007 – Construction Begins
- August 28, 2007 - Heating Begins
- August 29, 2007 - SVE System Activated
- October 18, 2007 - Air Sparging System Activated at 50 degrees C
- February 14, 2008 - Heating Ended (170 days of Heating)
- August 31, 2008 - SVE and AS systems turned off (SVE system operated for 368 days)



**Free Product  
Gasoline from  
SVE Knockout  
Tank**





**North Treatment Area on a Winter Day**

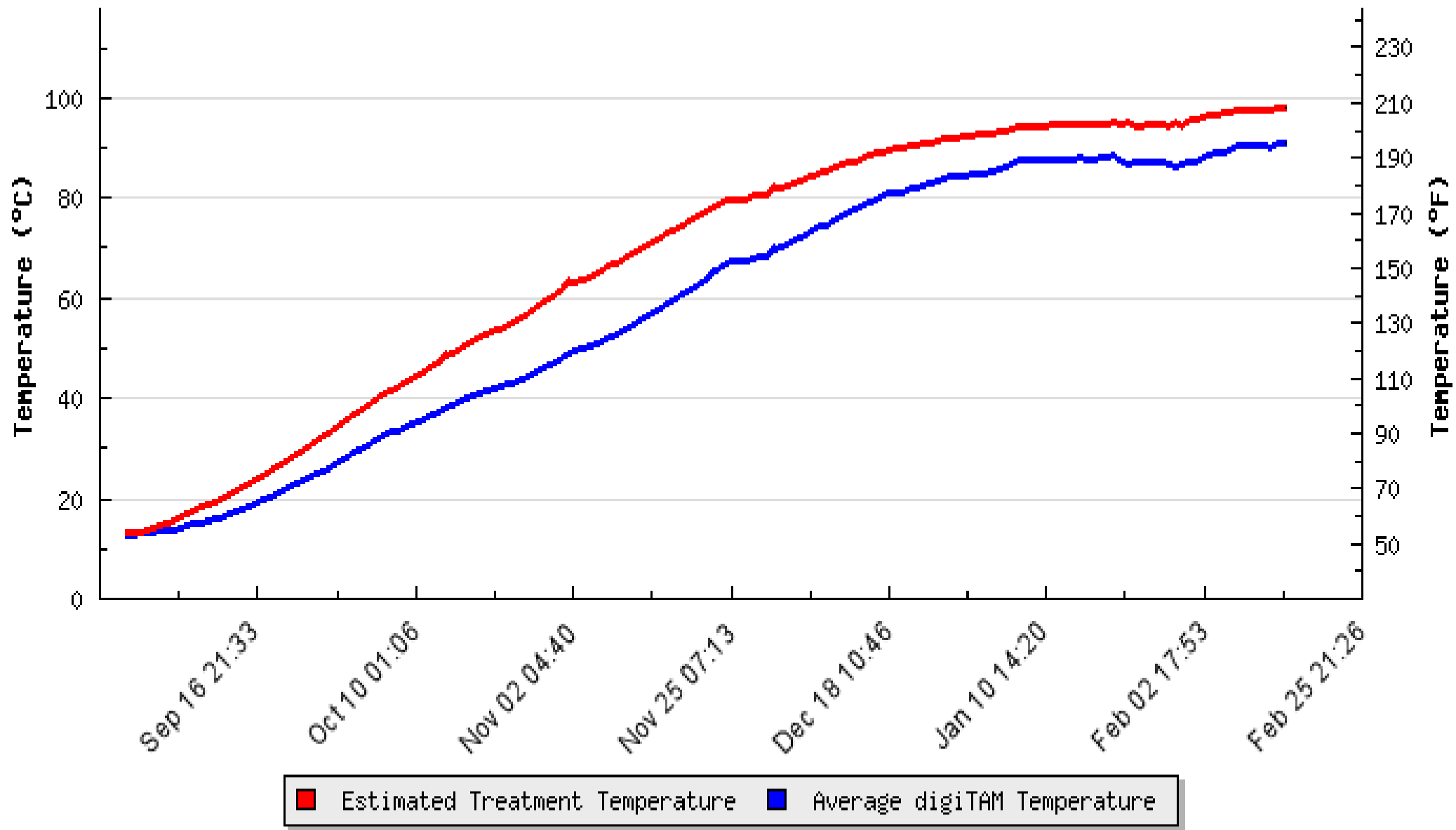




**Steam from Groundwater  
Monitoring Well GW-3**



## Subsurface Temperature from the Wellfield



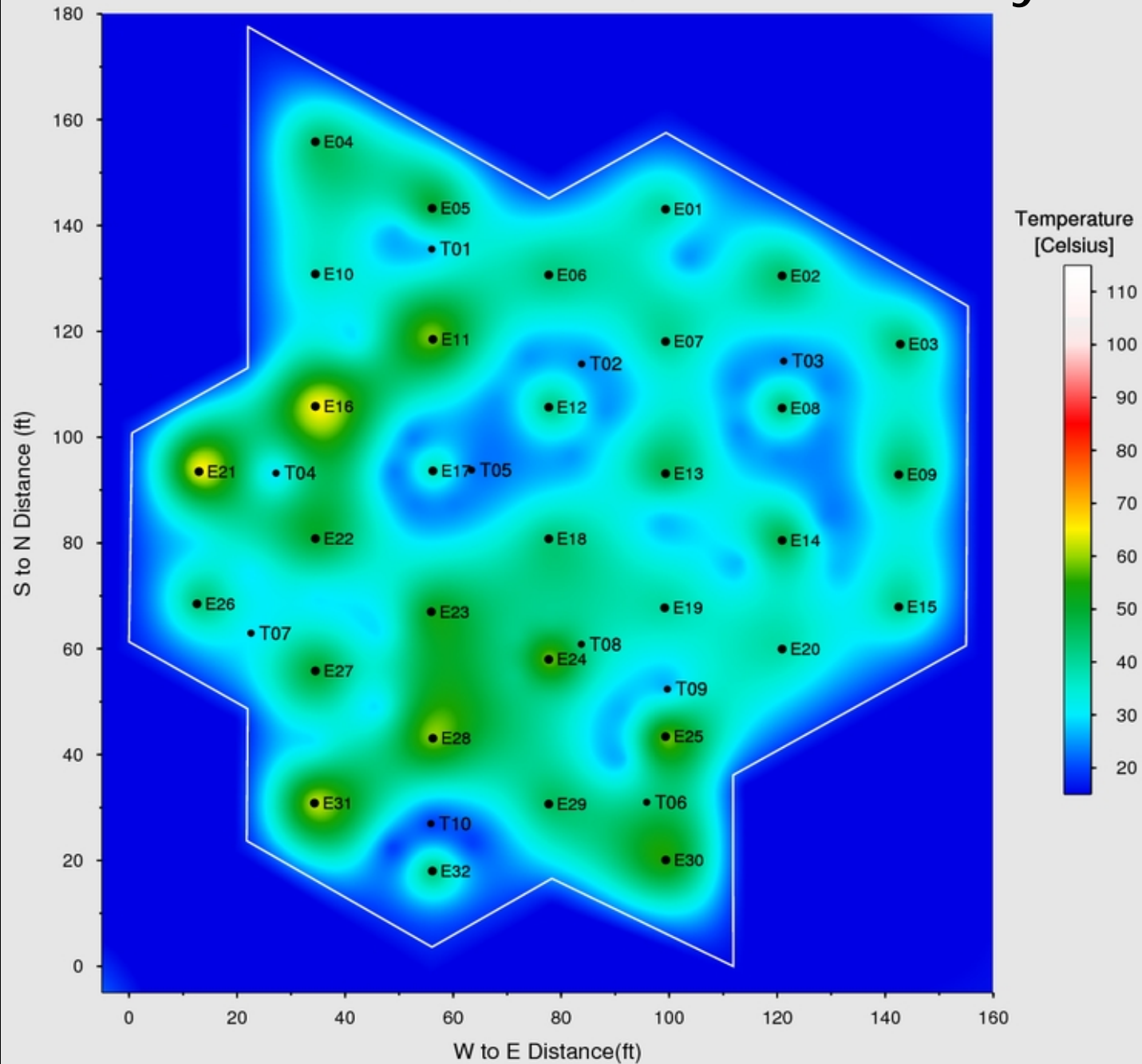
# Phase II ERH Treatment Zone





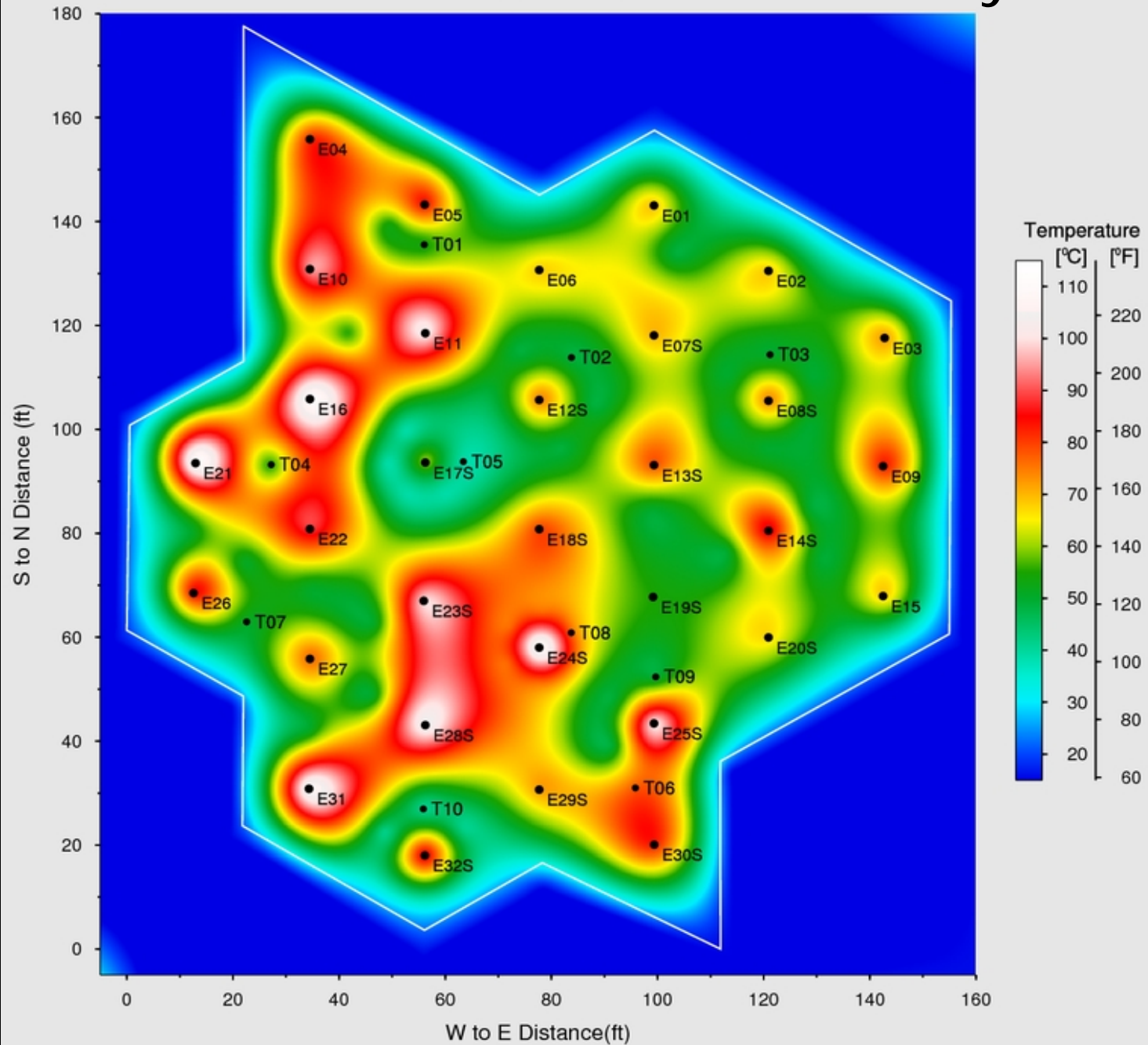
Thermal Contour Map - 09/27/07  
17.5 ft BGS - 3051.5 ft MSL

30 Days



Thermal Contour Map - 10/25/07  
17.5 ft BGS - 3051.5 ft MSL

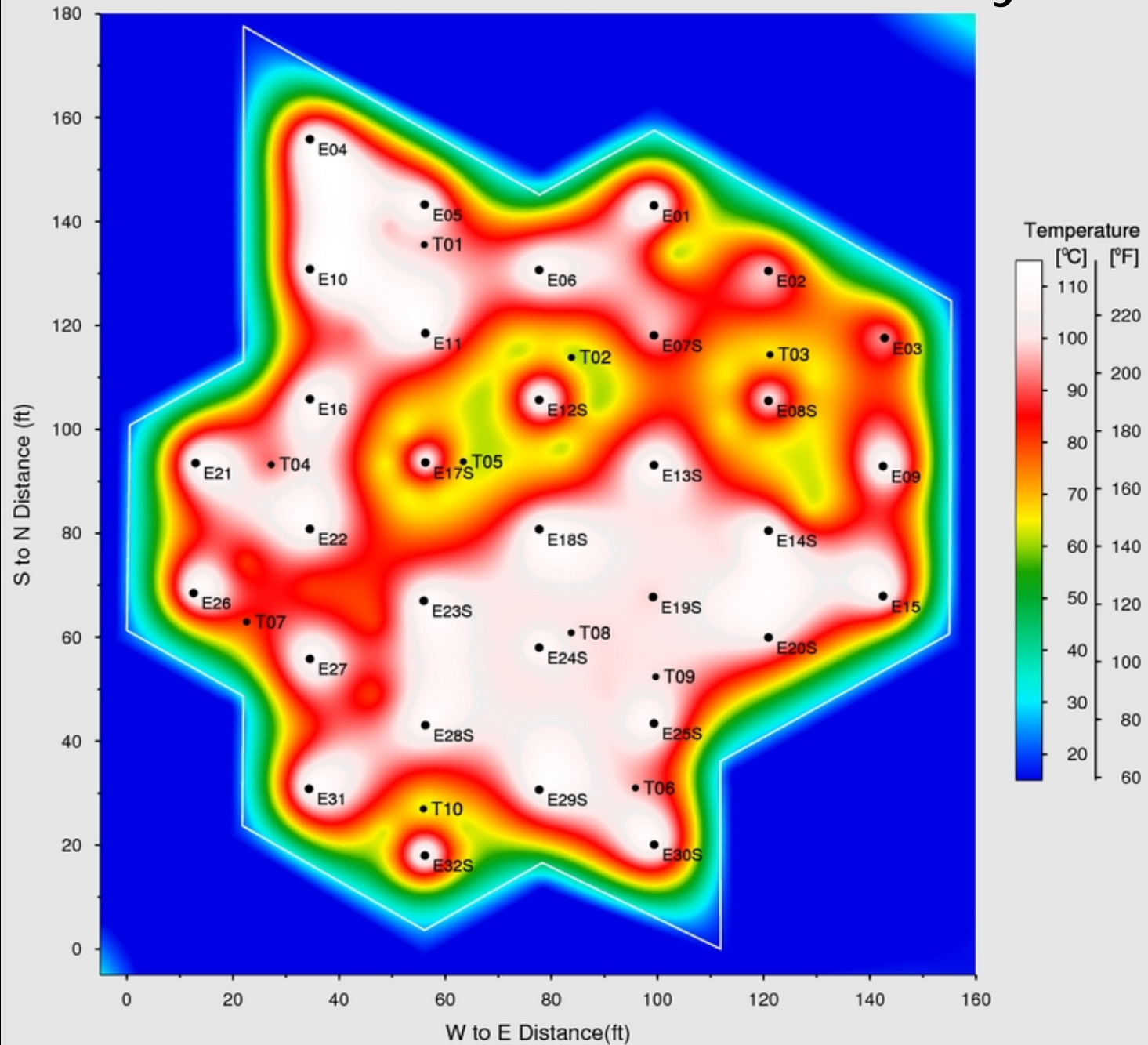
58 Days





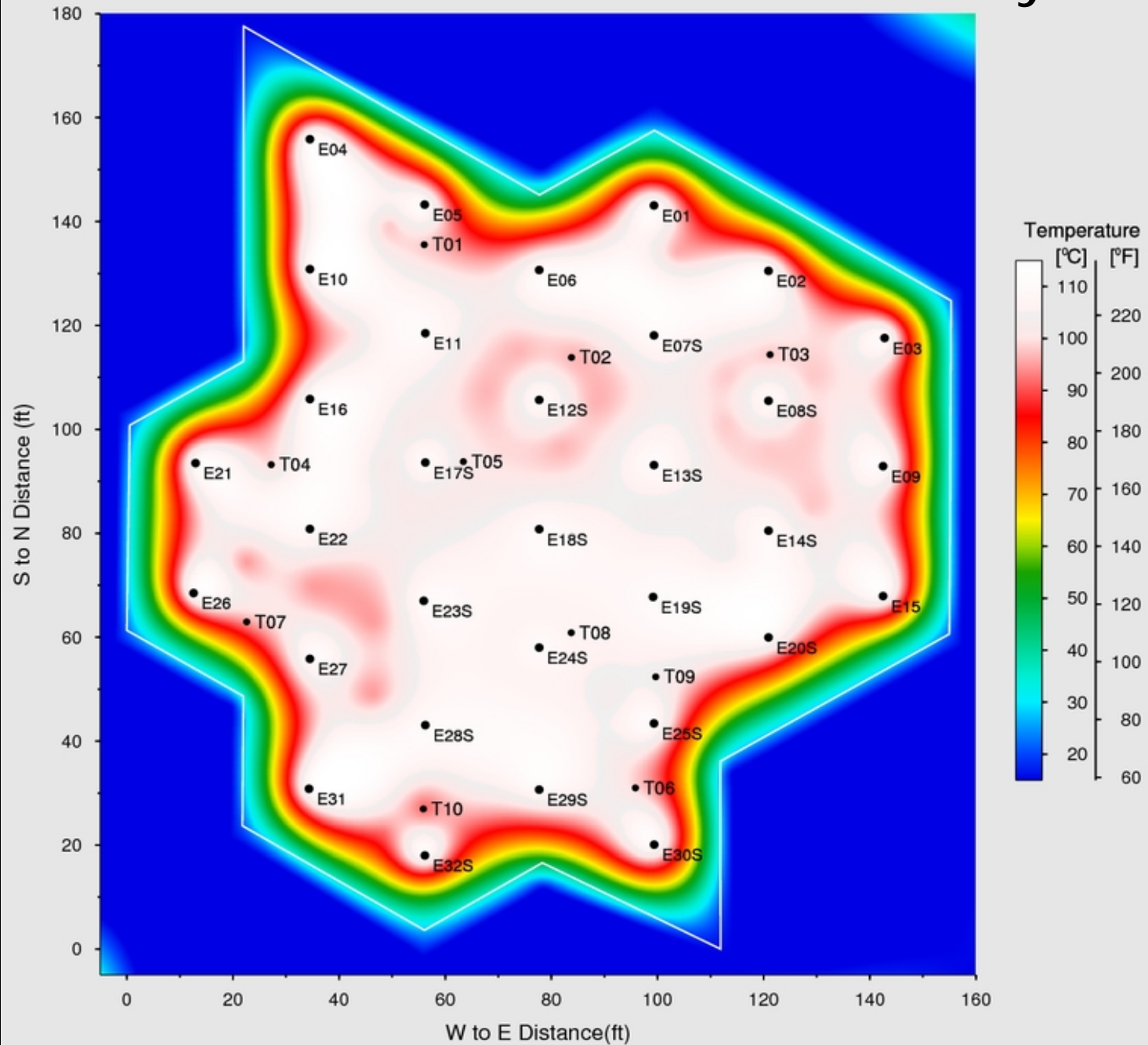
Thermal Contour Map - 11/22/07  
17.5 ft BGS - 3051.5 ft MSL

86 Days



Thermal Contour Map - 12/27/07  
17.5 ft BGS - 3051.5 ft MSL

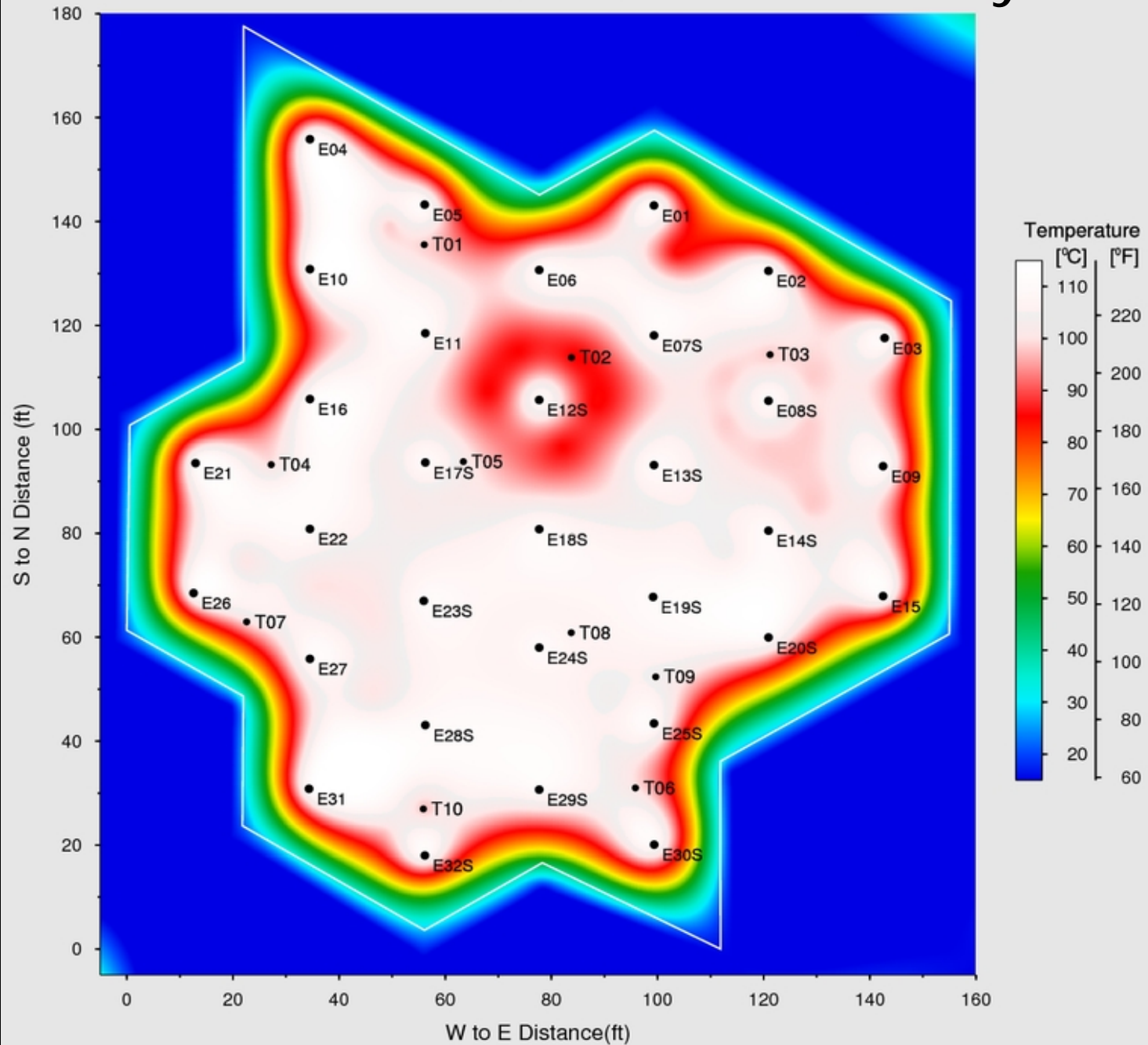
121 Days





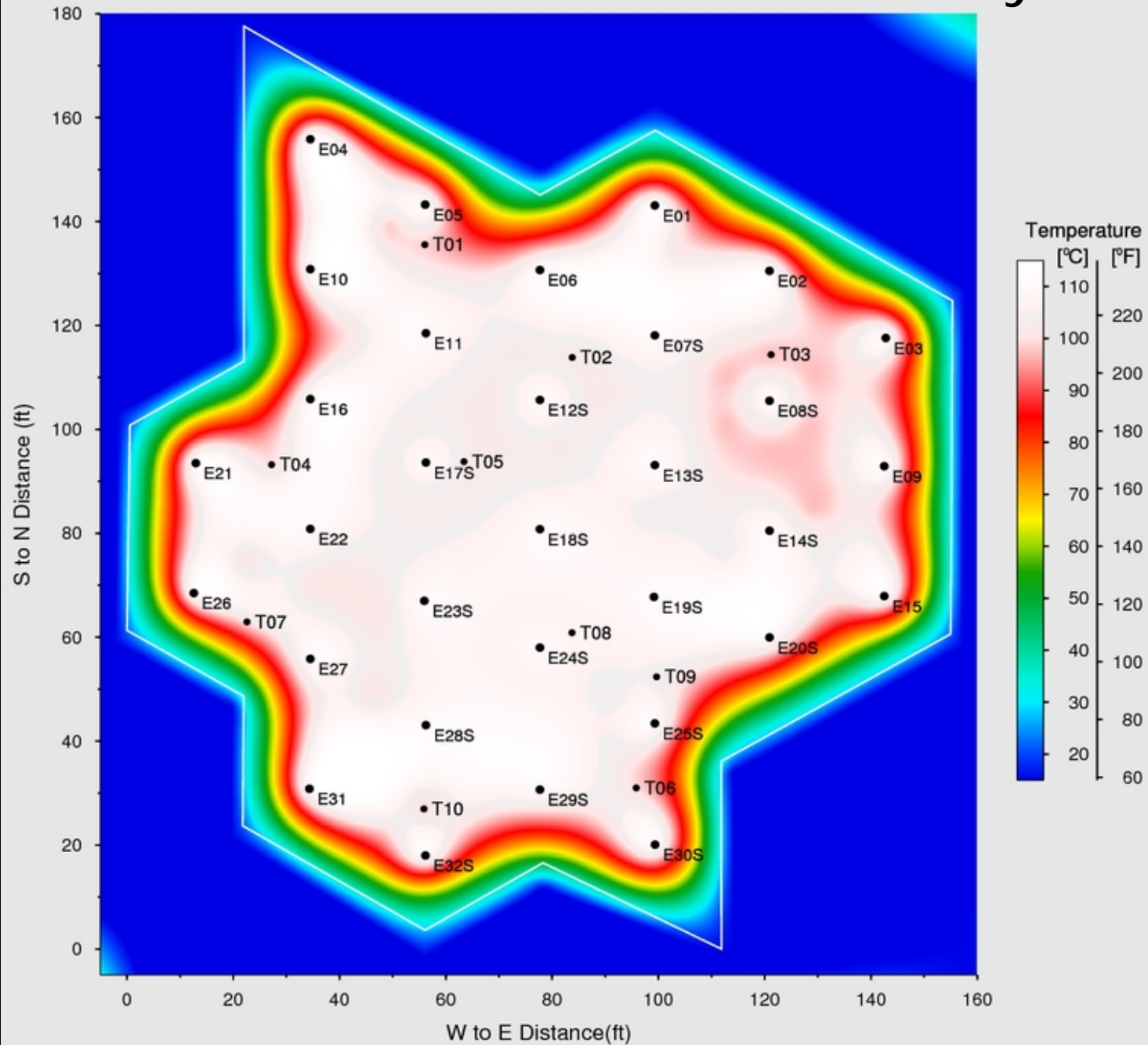
Thermal Contour Map - 01/24/08  
17.5 ft BGS - 3051.5 ft MSL

149 Days



Thermal Contour Map - 02/14/08  
17.5 ft BGS - 3051.5 ft MSL

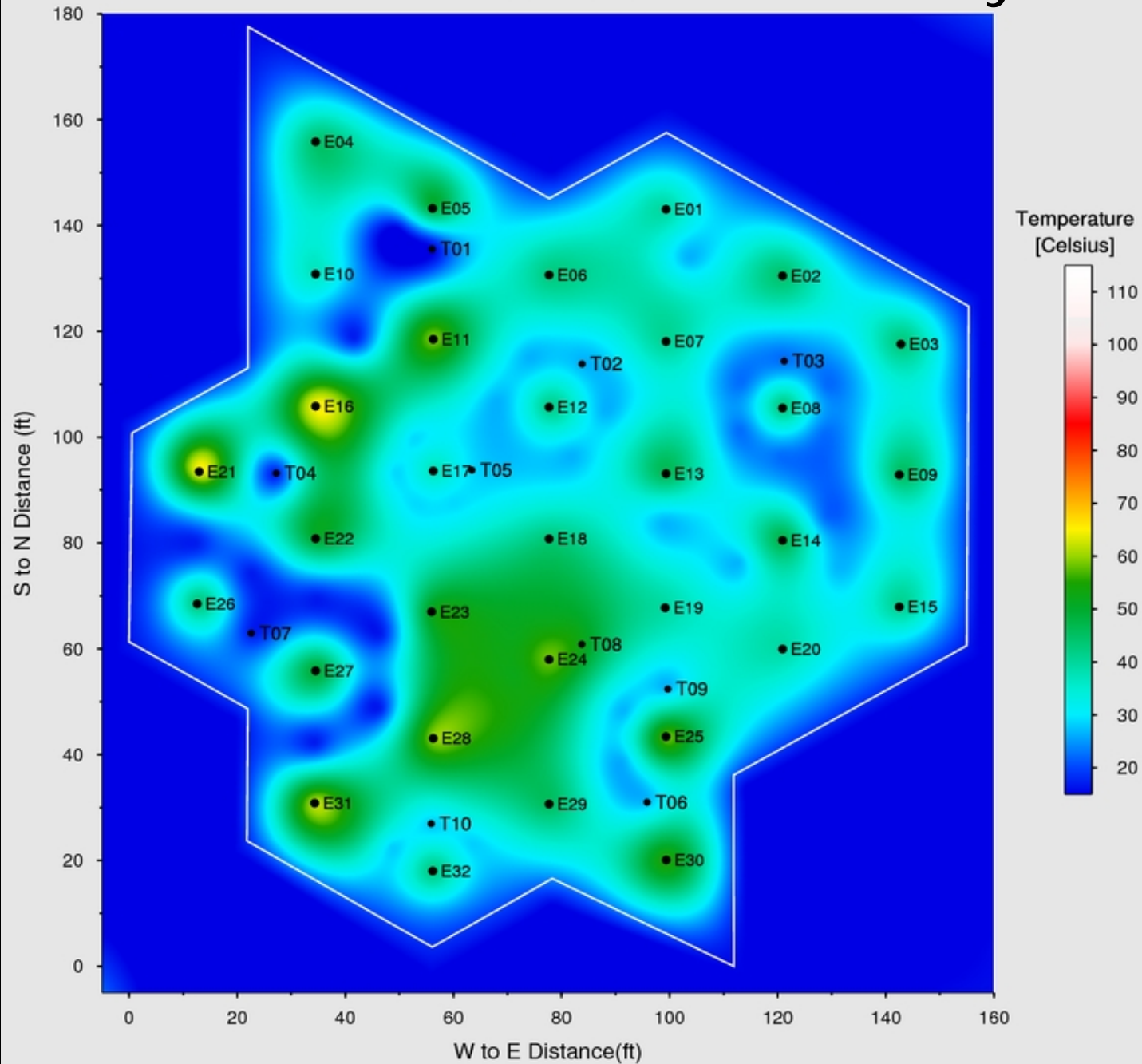
170 Days





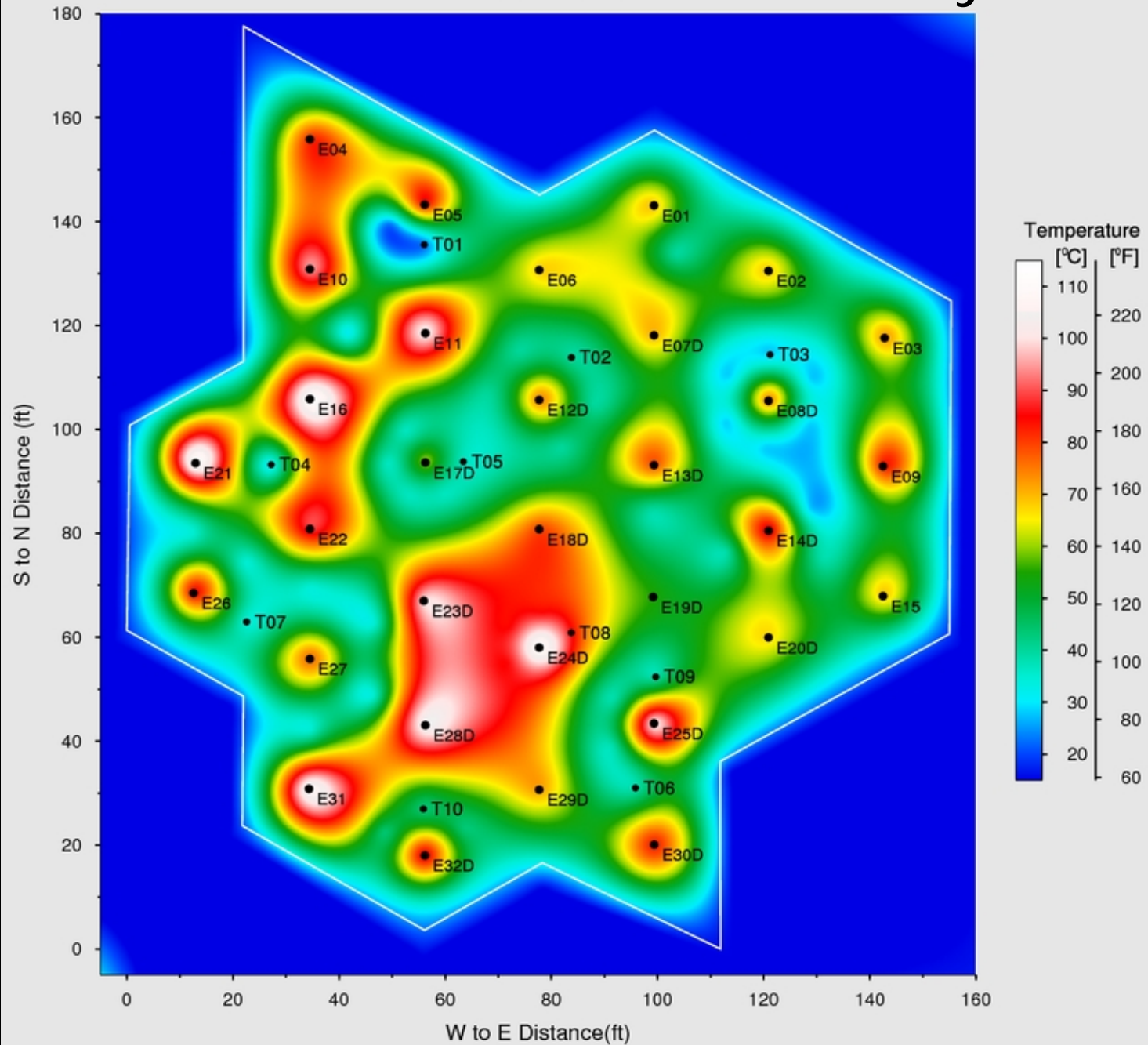
Thermal Contour Map - 09/27/07  
32.5 ft BGS - 3036.5 ft MSL

30 Days



Thermal Contour Map - 10/25/07  
32.5 ft BGS - 3036.5 ft MSL

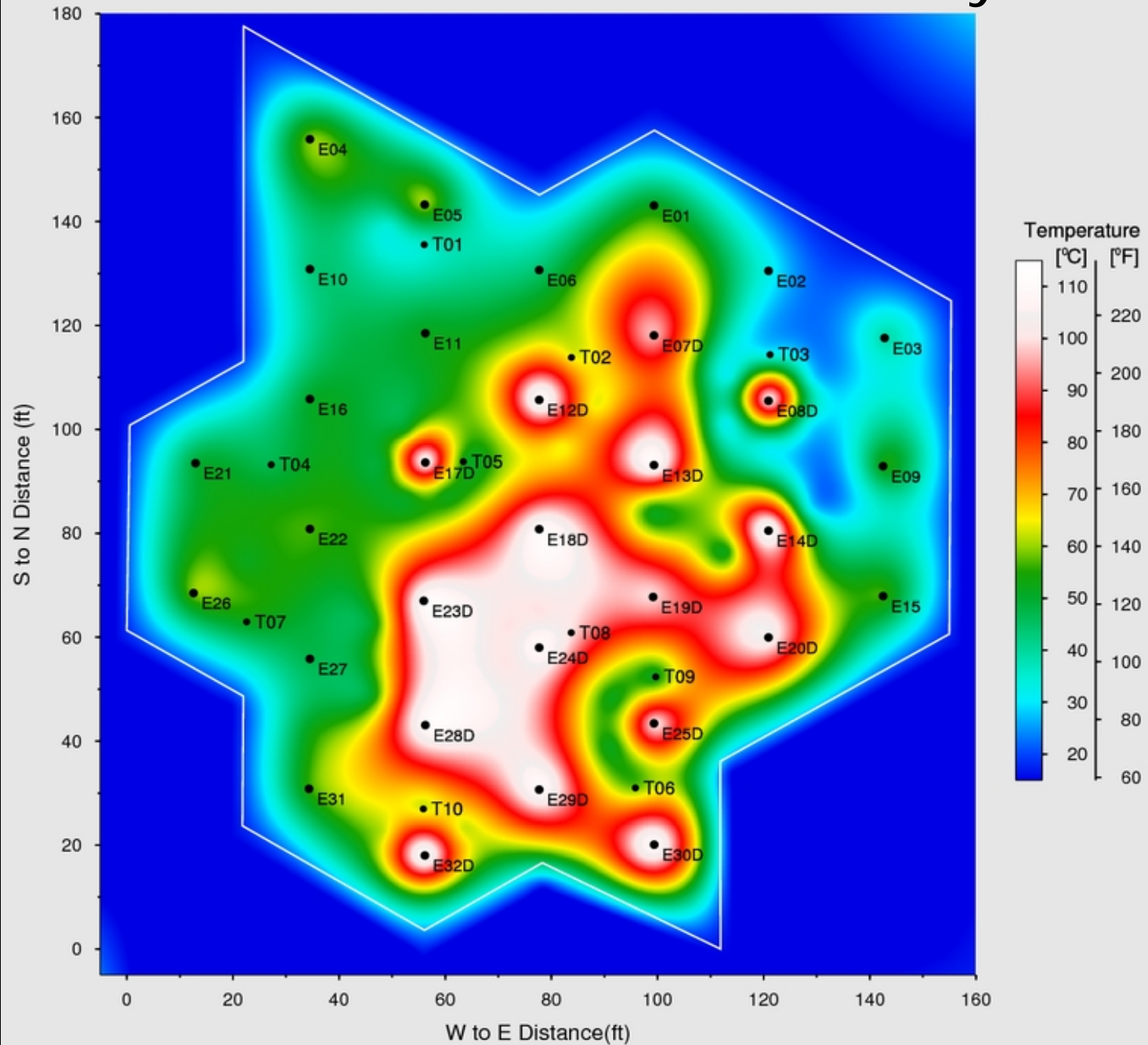
58 Days





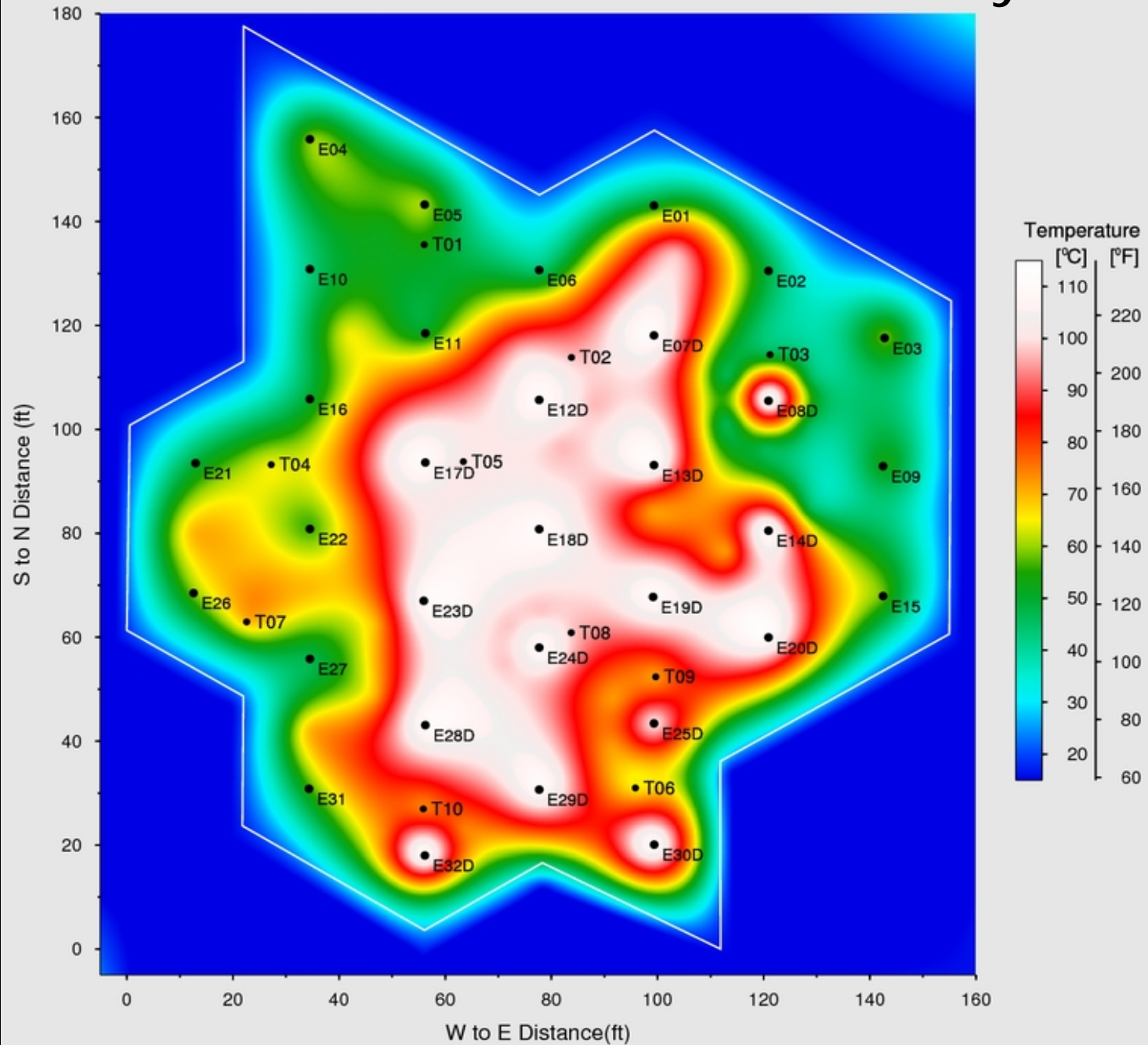
Thermal Contour Map - 11/22/07  
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86 Days



Thermal Contour Map - 12/27/07  
32.5 ft BGS - 3036.5 ft MSL

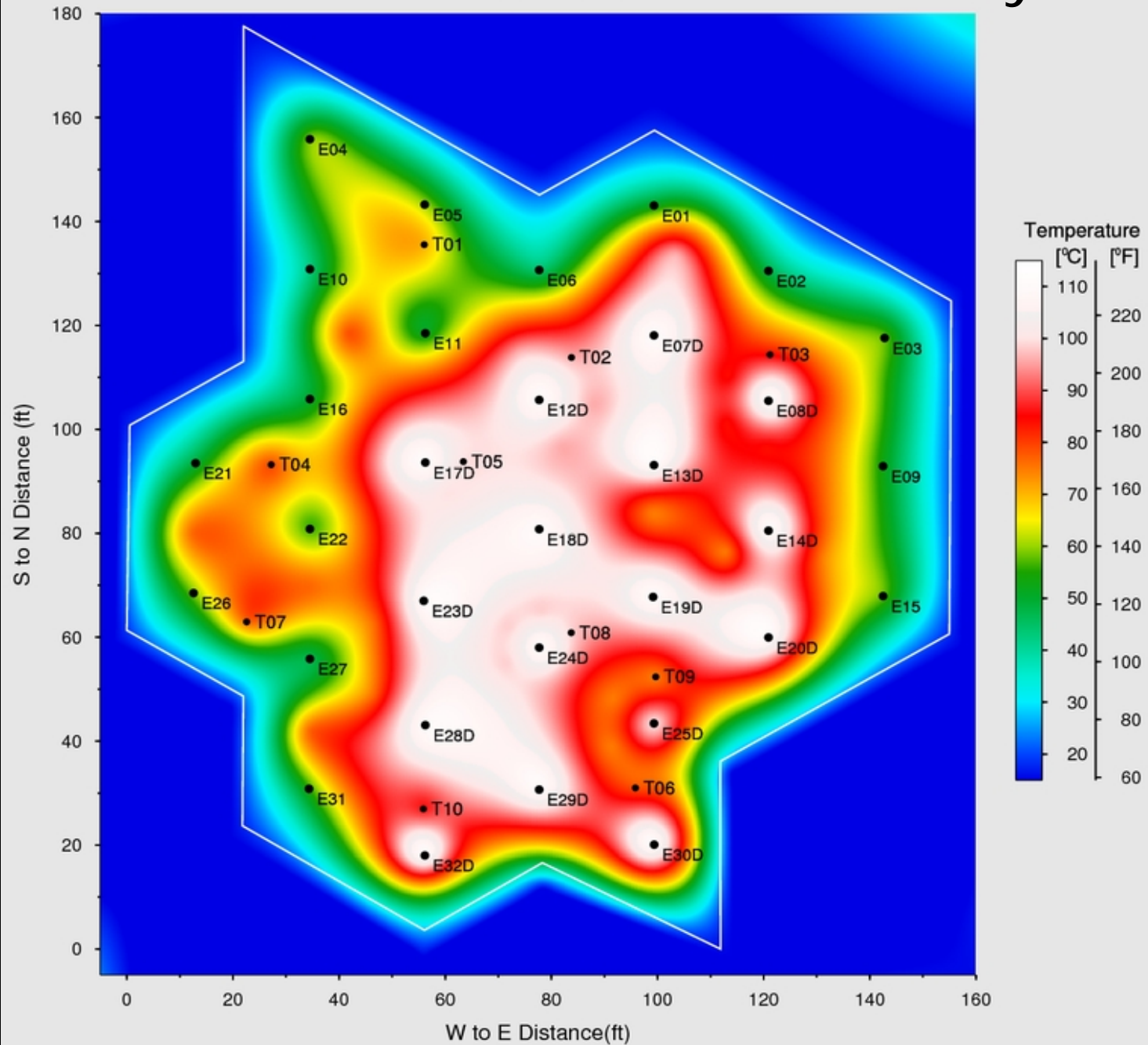
121 Days





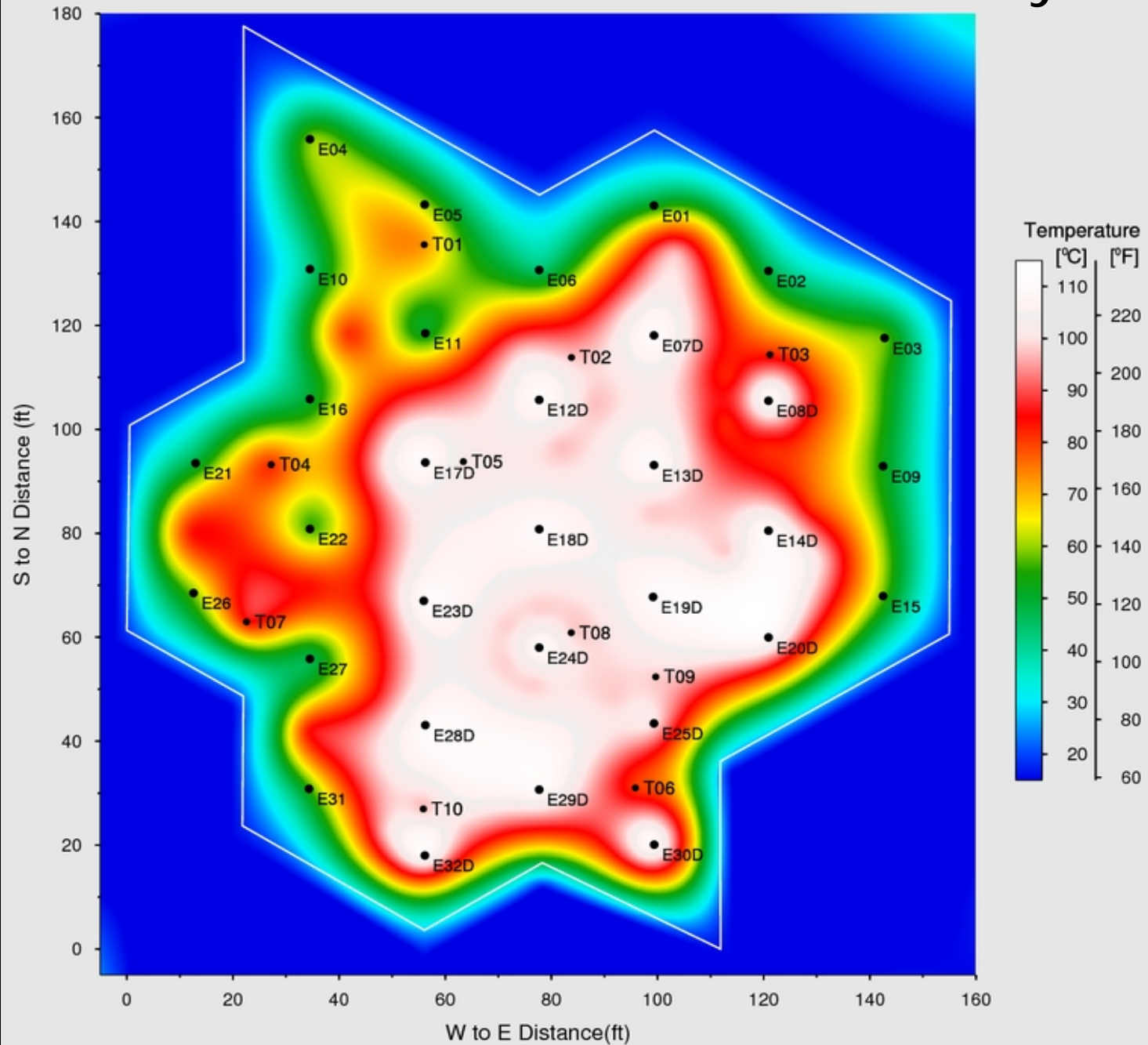
Thermal Contour Map - 01/24/08  
32.5 ft BGS - 3036.5 ft MSL

149 Days



Thermal Contour Map - 02/14/08  
32.5 ft BGS - 3036.5 ft MSL

170 Days





# Post-Heating Soil Confirmation Sampling

1.125-inch inside diameter Geoprobe™

Polyethylene Terephthalate Glycol (PETG) Liner





# RESULTS





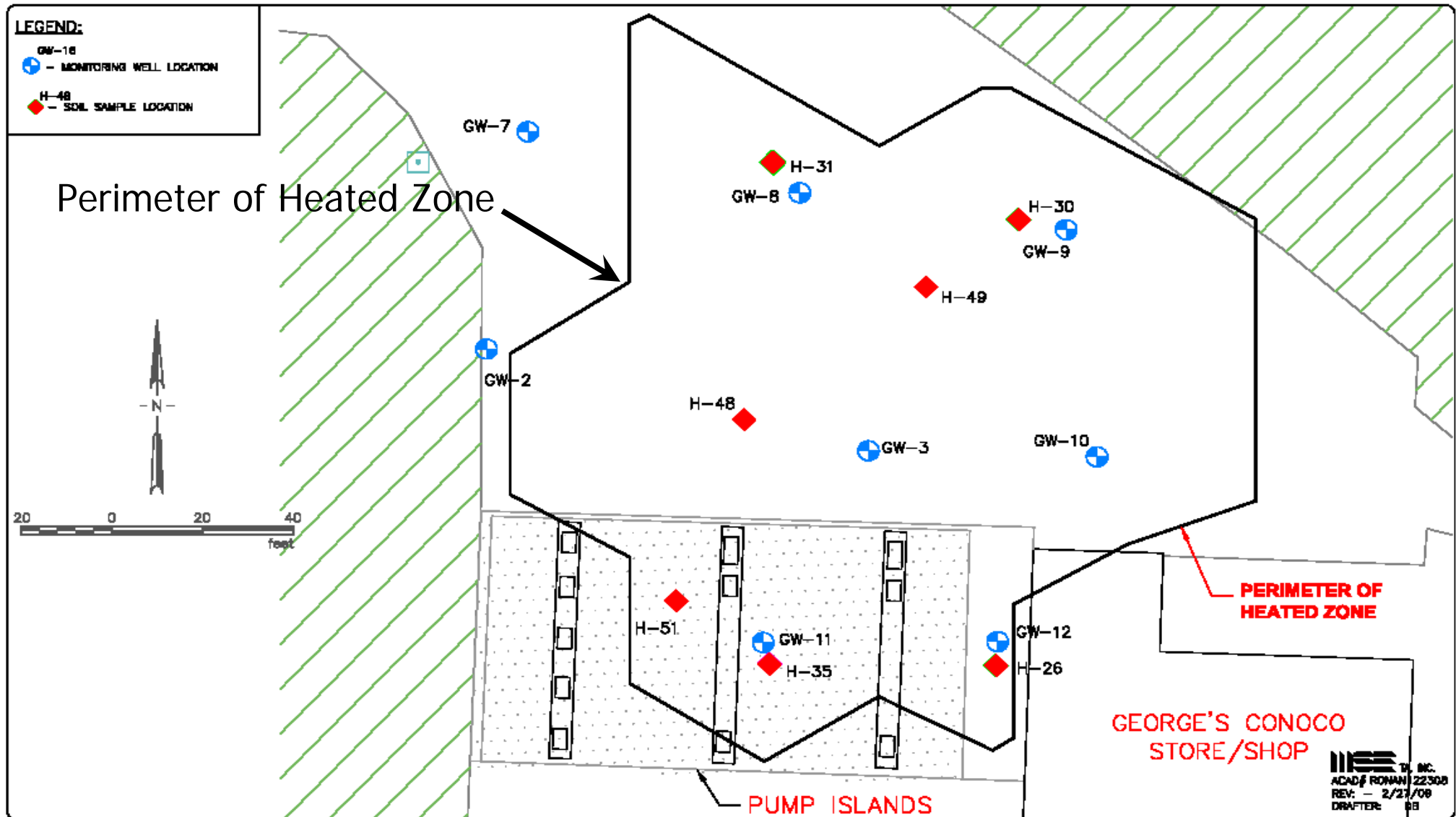


MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY

# Results

- Treatment Volume = 12,220 cubic yards
- Total Mass Removed
  - 21,940 pounds of gasoline
    - equivalent to 3,482 gallons of gasoline
- Time Frame
  - 170 Days of Active Heating
  - 368 days of SVE and Air Sparging

# Pre- and Post-Phase II ERH Soil and Groundwater Sample Locations





## Pre-and Post-Phase II ERH Soil Laboratory Analytical Data (mg/kg)

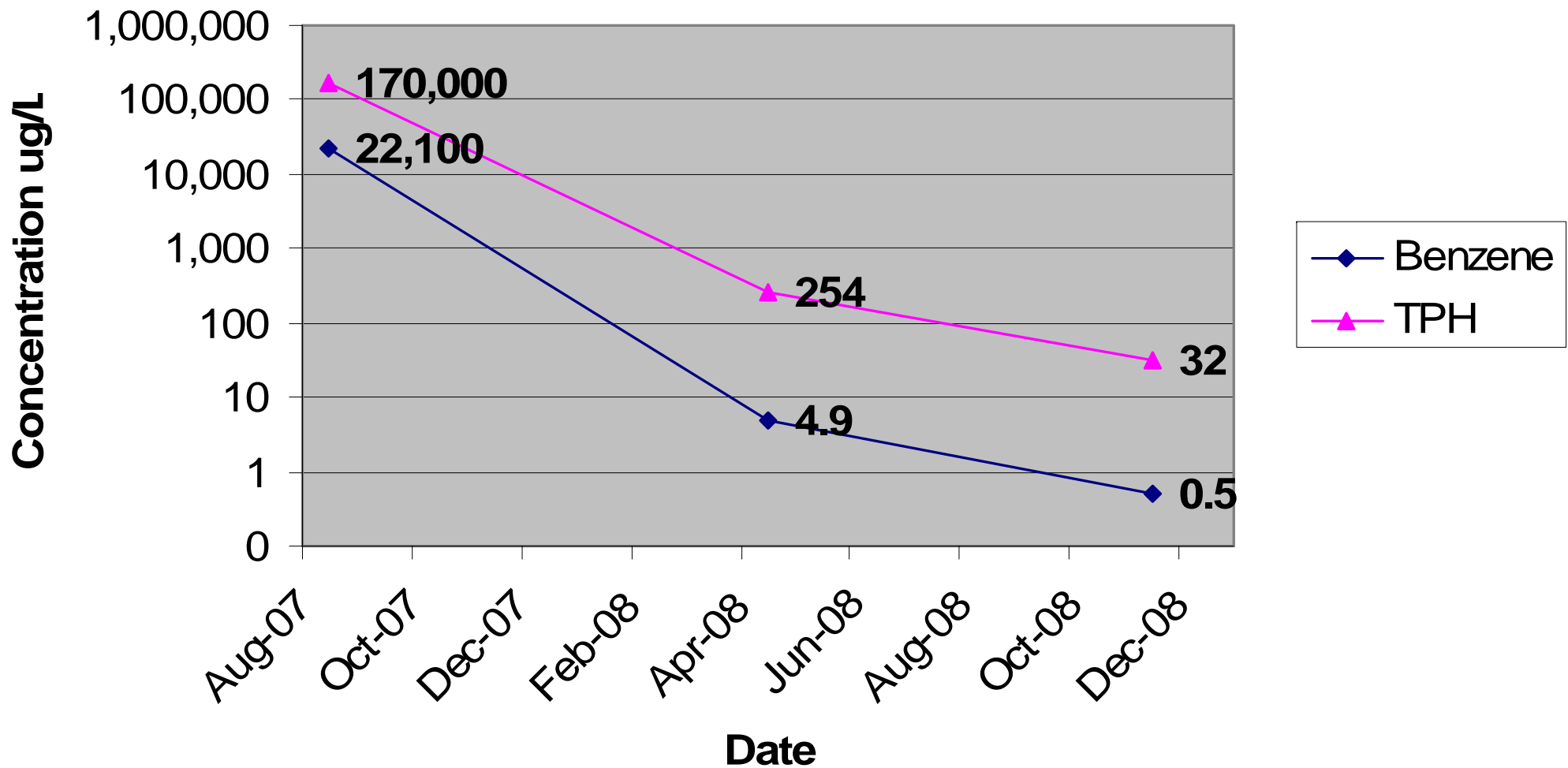
Sample ID	Depth Interval (ft)	Date Sampled	Benzene	TPH
<b>RBSL* Value</b>	<b>----</b>	<b>----</b>	<b>0.04</b>	<b>500</b>
H-30 East	16-20	7/12/2007	0.088	272
H-30 South (1-ft south)	16-19	4/2/2008	<0.061	<2.4
H-31 East	16-20	7/13/2007	1.4	519
H-31 South (16" south)	16-19	4/2/2008	<0.060	<2.4
H-35	12 - 16	3/5/2007	6.4	2,450
H-35 North (1-ft north)	12 - 16	4/2/2008	<0.056	<2.2
H-48	14-18	3/19/2007	4.3	203
H-48 South (1-ft south)	16-18	4/1/2008	<0.061	<2.4
H-49	14-18	3/19/2007	6.9	1,150
H-49 South (1-ft south)	14-17	4/1/2008	<0.058	<2.3

Pre- and Post-Phase II ERH Groundwater Laboratory Analytical Results (µg/L)

	Sample Date	Benzene	TPH
RBSL	----	5	1,000
GW-2	3/23/2007	22,700	114,000
	2/21/2008	<0.05	161
GW-3	3/8/2007	25,800	218,000
	2/21/2008	5.1	510
GW-7	8/3/2007	37	1,550
	2/20/2008	<0.50	107
	11/11/2008	<0.50	<20
GW-8	8/3/2007	2,200	22,100
	2/20/2008	<0.50	<20
	11/11/2008	<0.50	143
GW-9	8/3/2007	17	19,000
	2/20/2008	<0.50	56
	11/11/2008	<0.50	<20
GW-11	8/3/2007	22,100	170,000
	4/3/2008	4.9	254
	11/12/2008	<0.50	32
GW-12	8/3/2007	7,830	54,700
	4/3/2008	<0.50	<20
	12/11/2008	<0.50	1,070

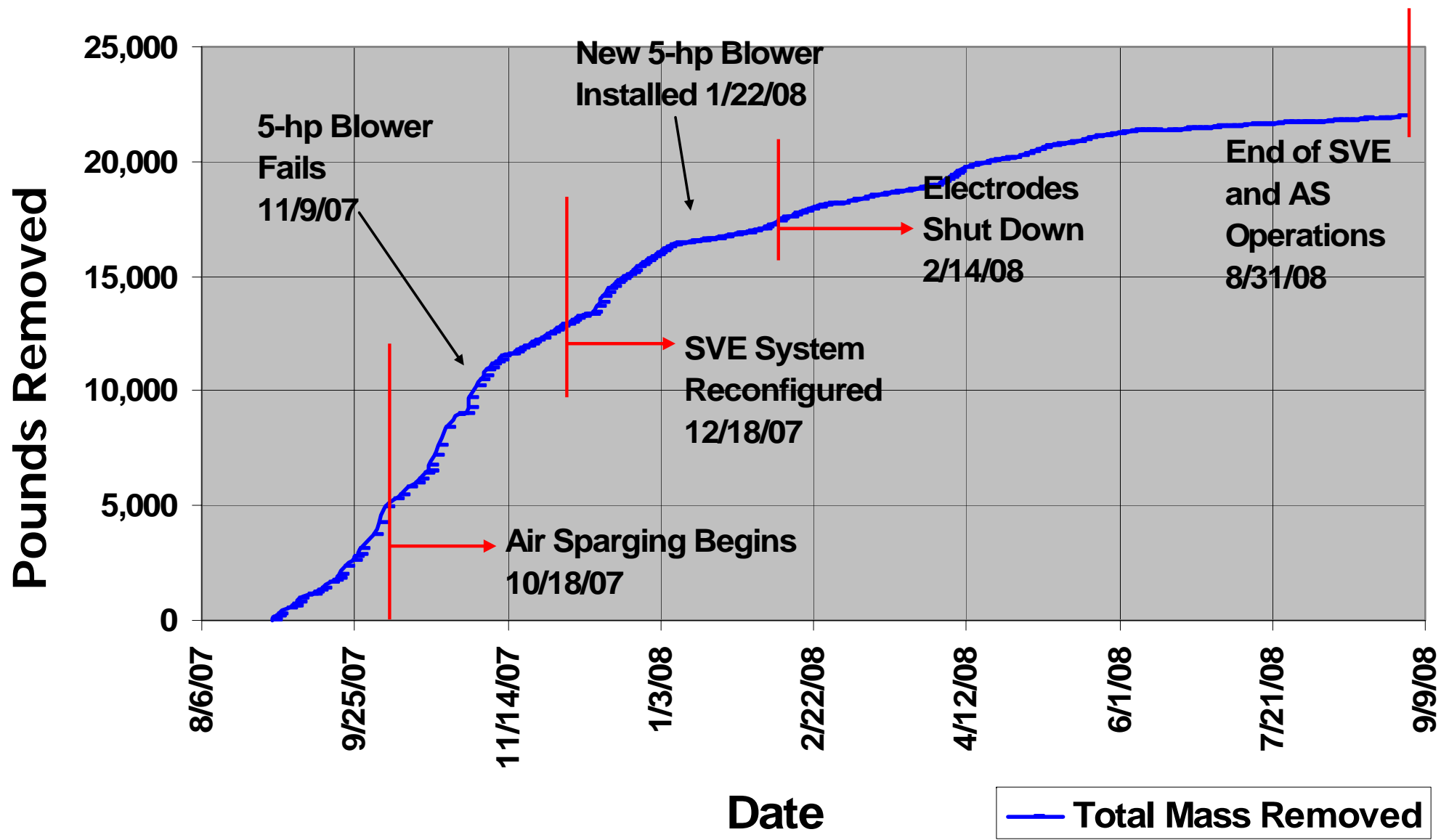


## Monitoring Well GW-11



Pre- & Post-Phase II ERH Groundwater Results

# Cumulative Mass Removed For All SVE Systems





# Project Costs

- Total cost was approximately \$900,000
- Electricity cost was \$97,114
  - Kilowatts used – 1,979,600; ~ \$0.05 kW/hour
- Cost per cubic yard (soil) - **\$74**
  - Significant reduction from \$130 per cubic yard – 2003 Phase I ERH Pilot Demonstration
  - Average cost for soil removal & disposal in MT; \$30 – \$90 per cubic yard (from MT PTRCB)



## Conclusions

- ERH technology combined with SVE and Air Sparging is an effective cleanup alternative for gasoline release sites with:
  - Free product
  - Silt and fine-grained sand
  - Deeper contamination that is not readily accessible through excavation
  - Contamination below the water table
  - On-site improvements such as highways and buildings



# Conclusions

- Met cleanup criteria within treatment zone
- ERH is a cost effective cleanup alternative when compared with other in-situ and ex-situ technologies
- ERH provides for expedited cleanup
- Air sparging with SVE is an effective alternative to total fluids pumping, typical of ERH Projects



## Added Benefits

- Potential for stimulated biodegradation downgradient of heated area due to residual heat



# Lessons Learned

- Make sure that you have a robust SVE system and are cautious when air sparging around structures
  - We had a vapor intrusion problem in the on-site building shortly after activation of air sparge system
  - Relocated business to temporary location until their new office was completed
- SVE wells could have been shallower to account for mounding of water table due to SVE and water injection to electrodes



## Lessons Learned

- Mud rotary - effective method for electrode installation
- A Geoprobe™ was successfully retrofitted for mud rotary drilling beneath the canopy
- Potable water did not maintain the integrity of the borehole
- Guar gum mixed with potable water was used as a drilling mud and was effective for maintaining borehole stability
- Flexibility in design and methods
- Start up system earlier in the spring (April/May)



# Phytoremediation Project on the Banks of Spring Creek

Jeff Kuhn with Hybrid Poplars  
Summer 2008





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**jkuhn@mt.gov**

**Questions ?**





# Pre-and Post-Phase II ERH Soil Laboratory Analytical Data (mg/kg)

Sample ID	Depth Interval (ft)	Date Sampled	MTBE	Benzene	Toluene	Ethyl benzene	Total Xylenes	Naphthalene	TPH
RBSL* Value	----	----	0.08	0.04	10	10	200	9	500
H-26 North	20-24	7/12/2007	<0.1	0.69	2	0.16	0.93	<0.1	6
H-26 South (1-ft south)	8-12	4/2/2008	<0.12	<0.058	<0.058	<0.058	<0.058	<0.12	<2.3
H-30 East	16-20	7/12/2007	<0.3	0.088	8.3	5	29	2.7	272
H-30 South (1-ft south)	16-19	4/2/2008	<0.12	<0.061	<0.061	<0.061	<0.061	<0.12	<2.4
H-31 East	16-20	7/13/2007	<0.5	1.4	20	8.1	49	4.3	519
H-31 South (16" south)	16-19	4/2/2008	<0.12	<0.060	<0.060	<0.060	<0.060	<0.12	<2.4
H-35	12 - 16	3/5/2007	<2.0	6.4	131	48	283	14	2,450
H-35 North (1-ft north)	12 - 16	4/2/2008	<0.11	<0.056	<0.056	<0.056	<0.056	<0.11	<2.2
H-48	14-18	3/19/2007	<0.20	4.3	20	5.4	29	1.9	203
H-48 South (1-ft south)	16-18	4/1/2008	<0.12	<0.061	<0.061	<0.061	<0.061	<0.12	<2.4
H-49	14-18	3/19/2007	<0.50	6.9	83	34	178	11	1,150
H-49 South (1-ft south)	14-17	4/1/2008	<0.12	<0.058	<0.058	<0.058	<0.058	<0.12	<2.3
H-51 (Grab Sample)	12 - 16	4/2/2008	<0.24	<0.12	<0.12	0.15	1.5	15	275

# Pre- and Post-Phase II ERH Groundwater Laboratory Analytical Results; µg/l

	Sample Date	MTBE	Benzene	Toluene	Ethylbenzene	Total Xylenes	Naphthalene	TPH
<b>RBSL</b>	----	<b>30</b>	<b>5</b>	<b>1,000</b>	<b>700</b>	<b>10,000</b>	<b>100</b>	<b>1,000</b>
<b>GW-2</b>	3/23/2007	<100*	<b>22,700</b>	<b>32,000</b>	<b>2,500</b>	<b>13,700</b>	<b>397</b>	<b>114,000</b>
	2/21/2008	<1.0	<0.05	<0.05	<0.05	1.3	81	161
<b>GW-3</b>	3/8/2007	<1,000*	<b>25,800</b>	<b>46,500</b>	<b>4,900</b>	<b>30,700</b>	<b>3,990</b>	<b>218,000</b>
	2/21/2008	<1.0	<b>5.1</b>	1.7	1.2	12	61	510
	11/11/2008	Well Damaged by Heat – Not Sampled						
<b>GW-7</b>	8/3/2007	<2.5*	<b>37</b>	122	47	289	12	<b>1,550</b>
	2/20/2008	<1.0	<0.50	<0.50	2.3	21	0.75 J	107
	11/11/2008	<1.0	<0.50	<0.50	<0.50	<0.50	<1	<20
<b>GW-8</b>	8/3/2007	<15*	<b>2,200</b>	<b>6,850</b>	<b>495</b>	3,130	63	<b>22,100</b>
	2/20/2008	<1.0	<0.50	<0.50	<0.50	<0.50	1.5	<20
	11/11/2008	<1.0	<0.50	<0.50	<0.50	0.88	55	143
<b>GW-9</b>	8/3/2007	<15*	<b>17<sup>#</sup></b>	<b>2,910</b>	<b>745</b>	3,870	98	<b>19,000</b>
	2/20/2008	<1.0	<0.50	<0.50	<0.50	<0.50	4.2	56
	11/11/2008	<1.0	<0.50	<0.50	<0.50	<0.50	<1	<20
<b>GW-10</b>	8/3/2007	<40*	<b>842</b>	<b>7,140</b>	<b>871</b>	4,780	89	<b>26,400</b>
	4/3/2008	Well Silted In – Development Attempt Failed						
<b>GW-11/</b>	8/3/2007	<400*	<b>22,100<sup>#</sup></b>	<b>38,600</b>	<b>3,970</b>	21,300	<b>500</b>	<b>170,000</b>
<b>GW-11R</b>	4/3/2008	<1.0	4.9	69	11	65	<1.0	254
	11/12/2008	<1.0	<0.50	<0.50	<0.50	<0.50	<1	32
<b>GW-12/</b>	8/3/2007	<40*	<b>7,830</b>	<b>17,300</b>	<b>1,120</b>	6,140	<b>107</b>	<b>54,700</b>
<b>GW-12R</b>	4/3/2008	<1.0	<0.50	0.47 J	<0.50	0.51	<1	<20
	12/11/2008	<1.0	<0.50	<0.50	8.4	481	20	<b>1,070</b>